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VOICE OF AMERICA HF CURTAIN ARRAY

INTERFERENCE STUDY

BY

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Project Engineer

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the results of a computer modeling investigation in which the interference to VHF and UHF communications/navigation equipments from a Voice of America HF relay station was determined. The radiating portions of the station were modeled using the Numerical Electromagnetic Code (NEC). Worst case interference models predict, based on the limited data available, taht the relay station and the nearby airport-based equipments are not compatible. Recommendations for improving the quality and quantity of input data are made. It is anticipated that this would reduce the predicted interference margins to acceptable levels.

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ABSTRACT

This report describes the results of a computer modeling investigation in which the interference to VHF and UHF communications/navigation equipments from a Voice of America HF relay station was determined. The radiating portions of the station were modeled using the Numerical Electromagnetic Code (NEC). Worst case interference models predict, based on the limited data available, that the relay station and the nearby airport-based equipments are not compatible. Recommendations for improving the quality and quantity of input data are made. It is anticipated that this would reduce the predicted interference margins to acceptable levels for some equipments.

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A. THE PROBLEM

The Voice of America is planning to locate an HF relay station a few miles from an international airport. Electromagnetic interference is a possibility because of the closeness of the airport communication/navigation equipments and the radiating portions of the relay station (the curtain antenna array and the open-wire transmission line). The out-of-band (VHF and UHF) radiation characteristics of the VOA HF system must be determined as part of an interference calculation. The NEC program, with acceptable limits, can provide that information. Once the radiated interference levels are predicted, they can be compared to acceptable interference levels established by the avionics users, providing margins of safety or interference.

B. GIVEN DATA AND PARAMETERS

The following represent information provided by VOA, describing the HF site and the avionics interference criteria:

1. HF Relay Station (6 - 17 MHz)

Six 250 KW AM transmitters; two transmitters diplexed into one 4 x 4 horizontal half-wave dipole curtain array (similar to a TCI 611), fed through 1,000 to 3,000 feet of 300 ohm, 4-conductor open-wire transmission lines. The spurious output level of each transmitter is at least -60 dB below rated output.

2. Avionics Equipment

The equipment listed below is located distances of from one to three miles from the HF relay station. The airport is at three miles, but the nearest approach of the flight path to the relay station is one mile.

Maximum acceptable interference levels, as established by the International Civil Aeronautics Organization (ICAO), as applicable to this scenario are, in dBW/M^2:

Service	Level
75 MHz VHF Marker	- 105.
120 MHz Aircraft ILS Localizer	- 136.8
120 MHz VOR	- 134.8
120 MHz Aircraft VHF Communications	- 136.2
120 MHz Ground VHF Communications	- 136.8
330 MHz Aircraft ILS Guide Path	- 116.8
1200 MHz Aircraft VOR/DME	- 102.

C. THE APPROACH

Since a VHF/UHF (out-of-band) performance prediction is required for the antenna and transmission line, and was nonexistent at commencement of the study, a step-by-step plan was developed to go from the known HF characteristics of the radiating system to the unknown VHF/UHF performance.

These steps were followed:

1. A full-model of the HF array was developed using NEC; the results were compared to the TCI published patterns, validating the modeling process in-band.

2. A vertical and a horizontal "cell" of the array were modeled at HF. Array theory was applied to produce the full array performance, demonstrating the principle for later application at VHF/UHF.

3. The smaller "cell" models were then run on NEC at VHF/UHF to produce out-of-band characteristics for these workable-sized representations of the antenna system.

4. Expected full-array out-of-band characteristics were calculated from the above, applying the same array theory. This established radiation for the antenna array portion of the RF system of the relay station.

5. The transmission line was modeled as an explicit wire model on NEC allowing prediction of radiation from the line at VHF/UHF.

6. The contribution of total RF system radiation caused by the transmission line was then established for use in the interference assessment portion of the study.

7. The worst case signal levels produced by the VOA system were estimated from (4) and (6) above, and interferences noted.

D. THE HF MODEL OF THE ARRAY

The HF array was modeled using NEC. The radiation patterns which were produced were very close to the published predicted patterns from TCI. Figures 1a and 1b demonstrate a sample of the correlation of patterns. This validates the numerical model at HF and permits the next step: a model of a portion of the array at HF, later to be extended to VHF/UHF.

E. THE VHF MODEL OF THE ARRAY

As with all numerical analysis, model sizes must be limited to those which are reasonable both from an economic and time standpoint. A good example of a system which cannot be fully extended from HF to VHF/UHF is the VOA curtain array. A full-blown analysis of any radiating system using the NEC program or any other similar model is limited in terms of wavelengths of extent of the structure. The in-band HF model was large but not excessive, however, the full model run at the lowest VHF frequency of interest would have proven excessive in computer resource consumption.

To bound the VHF/UHF radiation, a vertical and a horizontal four element "cell" was run and validated at HF, then exercised at VHF/UHF. The HF cell model agreed as expected with the full model. When run at VHF/UHF the vertical and horizontal cells yielded 8 dB and 15 dBi gains respectively, resulting in:

$$\frac{8 + 15}{2} = 11.5 \text{ dBi} \quad \text{peak gain for the array.}$$

The average gain was approximately -7.5 dBi.

F. THE TRANSMISSION LINE MODEL

A 2000' long line was modeled (no bends were assumed) to determine the attenuation and radiation characteristics out-of-band at VHF/UHF. The attenuation per wavelength and total attenuation for a 2000' run were calculated

and found to dominate the radiation from the line at lower frequencies. At UHF, radiation patterns were examined and found to produce 12 dBi peak and -7 dBi average gain. The following table summarizes the NEC modeling:

Frequency	Attenuation /λ	Total Attenuation (2000')
75 MHz	0.04 dB	6 dB
120 MHz	0.045 dB	11 dB
330 MHz	0.06 dB	40 dB*
1200 MHz	2.2 dB	-- *

* = Radiation Dominates (12 dBi peak/-7 dBi average)

G. GEOMETRY OF THE AIRPORT/ANTENNA FARM

Figure 2 demonstrates that the lines of bearings for the VOA arrays (320°, 350° and 10° to 50°T) fairly well cover the airport runway and flight path. The closest distance to the flight path is one mile and the airport runway is at three miles. The worst case free space path loss calculated at one and three miles provides a range of possible values for interference calculations:

FREE SPACE LOSS

	75 MHz	120 MHz	330 MHz	1200 MHz
at 1 mile	- 73 dB	- 78 dB	- 86 dB	- 97 dB
at 3 miles	- 83 dB	- 88 dB	- 96 dB	-107 dB

H. PREDICTED INTERFERENCES

1. HF Transmitter Emissions (-60 dB below output)

With 250 KW per transmitter and two transmitter per antenna, three antennas per site, the range of emitted VHF/UHF power runs from:

0.25 watts (-6 dBW) to 3.0 watts (+5 dBW)

2. Interference Equation

$$S_{\substack{\text{Receiver}\\ \text{dBW/}M^2}} = P_{\text{Transmitter}} + G_{\substack{\text{Antenna or}\\ \text{Transmission}\\ \text{Line}}} - L_{\substack{\text{Free}\\ \text{Space}}} - L_{\substack{\text{Transmission}\\ \text{Line}}} + \underbrace{4\pi - \lambda^2}_{\substack{\text{Effective}\\ \text{Apperture}\\ \text{Factor}}} \text{ dB}$$

where

S is Power Density,

P is Power,

G is Gain (radiation),

and L is Loss, all in decibels.

NOTE: Transmission line losses are actually long-wire type radiation losses or energy leakage along the line.

3. Interference Margins

When the interference power balance equation is exercised, considering ranges of values for some of the terms, the predicted range of received power densities is obtained. Comparing this to the allowable signal levels results in acceptable performance from an interference viewpoint, or from an interference margin (unacceptable).

The following limits are calculated for the conditions of one transmitter, three mile distance and average gains, as a best case and six transmitters, one mile distance and peak gains as the worst case. Thus, the values listed in the table cover the range of possible levels based on the limited data available at this time.

Frequency Band MHz	Interference Margin dB
75	+11.5 to + 15.5
120	+37 to + 77
330	+10.5 to + 50.5
1200	-15.5 to + 24.5

I. RECOMMENDATIONS

The rather dismal prospects for coexistence of the HF relay station and the airport avionics represent, to a large extent, quite limited information and the HF relay station components. If the following information is obtained, it is likely that the margins presented here can be reduced, and in some cases, made negative (safe operation).

1. The transmitter output spectrum from 75 - 1200 MHz might be well below the rated -60 dB. This should be ascertained.

2. The coupler/balun response has been neglected in this study, yet it must have out-of-band performance which would provide relief from the calculated signal levels.

3. No transmission line bends/corners were assumed. Since bends contribute substantially to out-of-band radiation, the details of the line layout are needed.

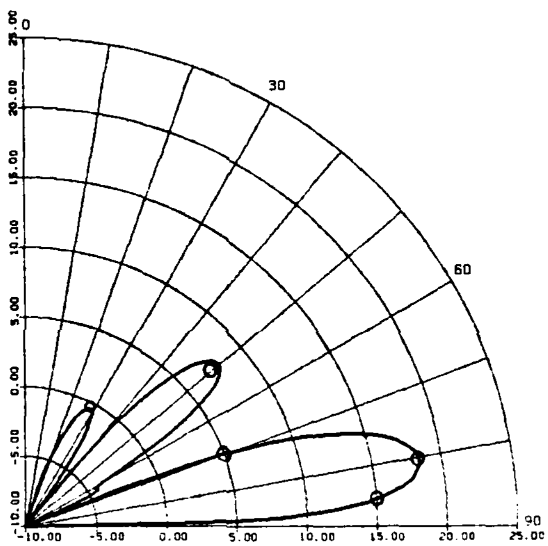
4. The HF array's feed harness is an unknown. For this worst case analysis, all elements were assumed to be such that VHF/UHF radiation from each element was in-phase at broadside, a highly unlikely situation. Feed harness details will enable out-of-band predictions which are more realistic.

5. The ICAO interference criteria did not match some of that provided by equipment manufacturers. This should be resolved and one clear set of criteria formed.

An alternate, and possible more easily obtained set of data, which would prove quite enlightening for this problem involves a ground-based and aerial field intensity survey of an existing VOA site, such as the one at Delano, California. A properly conducted survey could bracket expected levels of out-of-band interference and is recommended at this time.

VOA SRI LANKA CURTAIN ARRAY/TCI 611

ELEVATION PATT/PERF GND/ 8.00 MHZ



O = (TCI Data -3 dB)

Figure 1a. NEC VERSUS TCI HF ARRAY MODEL

VOA SRI LANKA CURTAIN ARRAY/TCI 611

AZ PATT/10 DEG EL ANG/PERF GND/8.00MHZ

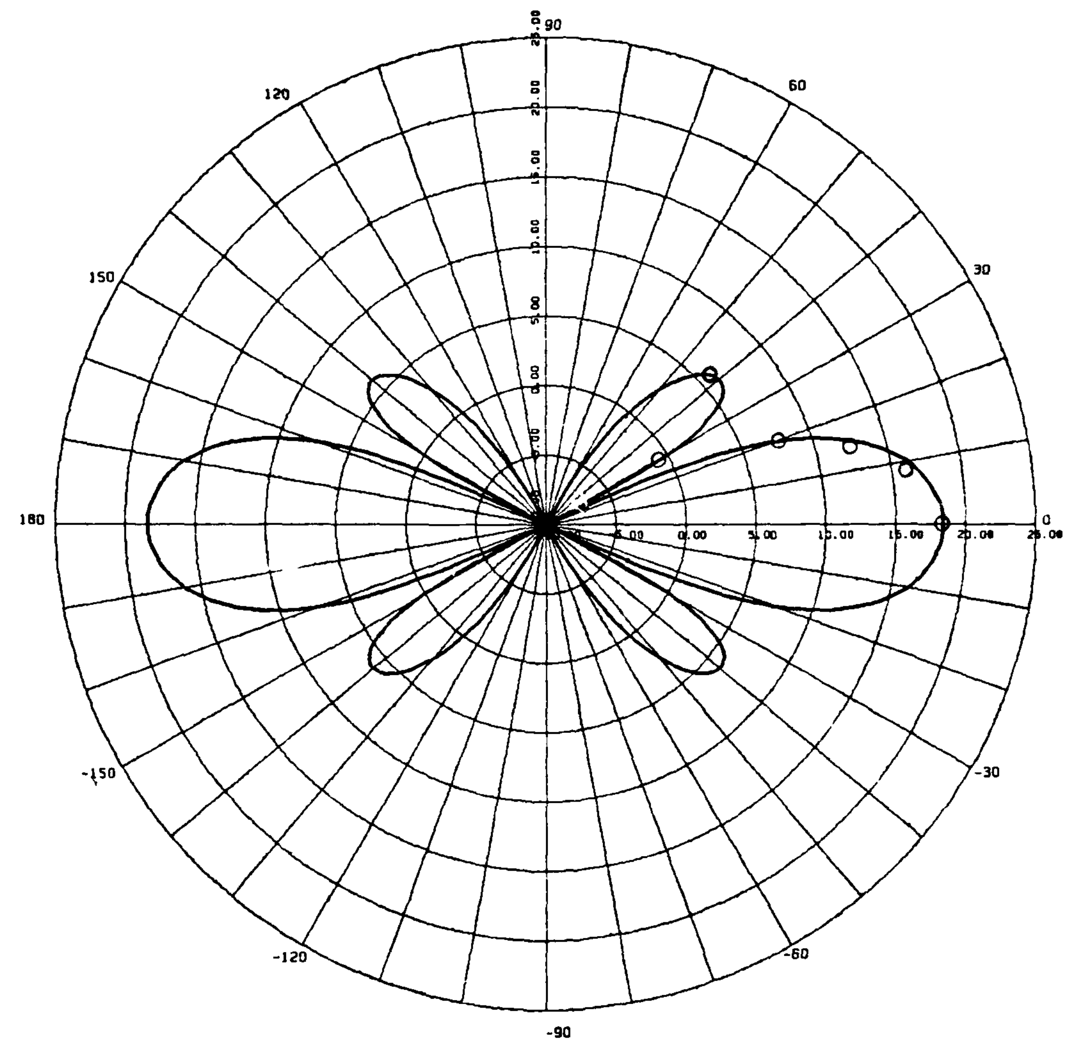


Figure 1b. NEC VERSUS TCI HF ARRAY MODEL

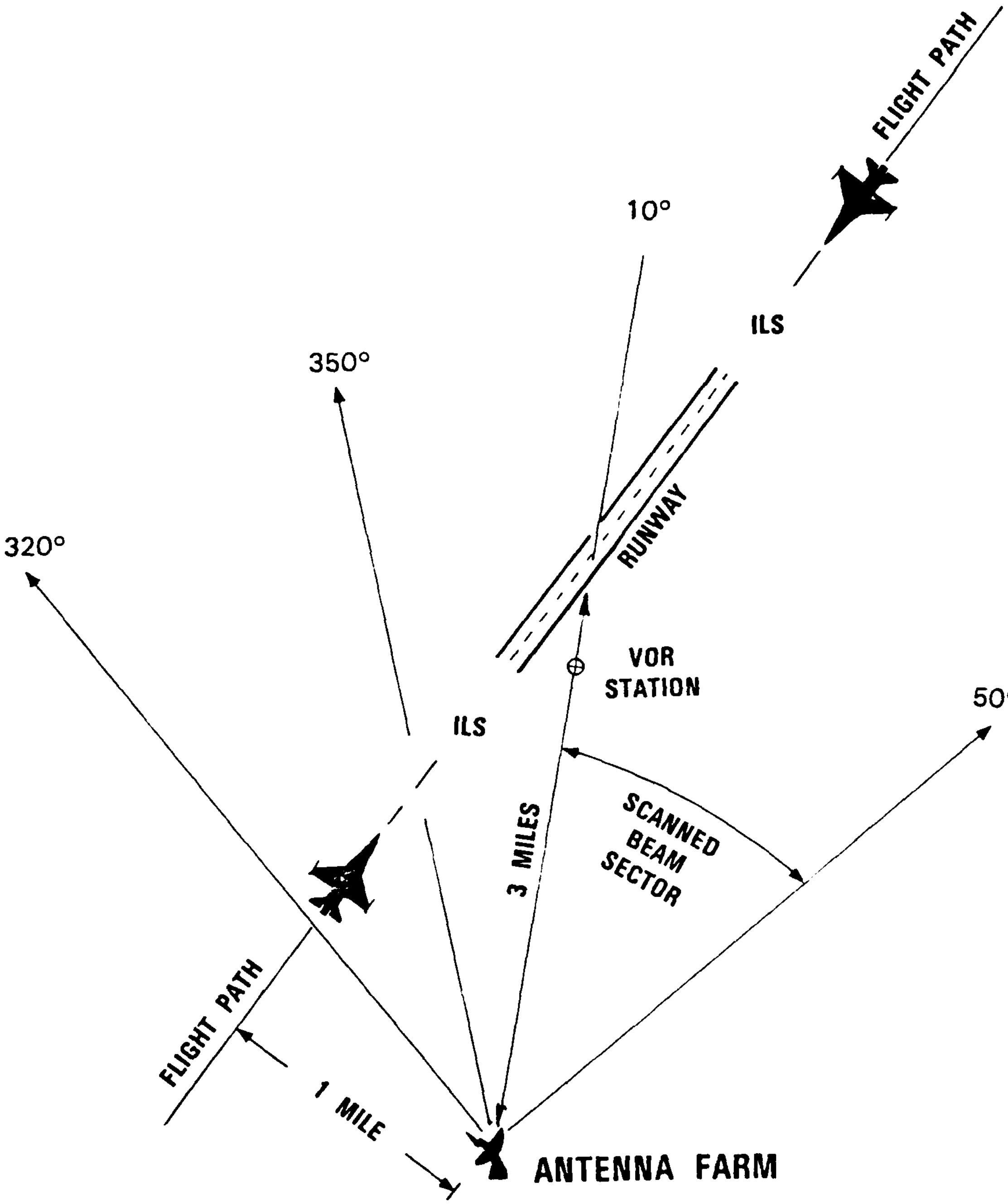


Figure 2. AIRPORT AND ANTENNA FARM

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